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SMARA UPDATE

The Quarterly Newsletter of the Department of Conservation - Office of Mine Reclamation

Governor Names New Chair, Members To State Mining And Geology Board

On March 15, 2001 Governor Gray Davis announced the designation of Allen M. Jones as chair, and the appointments of Brian R. Baca, Robert D. Hablitzel, Maureen F. Rose, Robert E. Tepel and Donna M. Thompson as members of the State Mining and Geology Board.

Mr. Jones, 51, of San Diego, has served on the Board since 2000. He has served as Vice President for H. G. Fenton and Company since 1990. Previously, Mr. Jones served as the Deputy Planning Director for the City of San Diego. He is a member of the American Planning Association, Urban Land Institute and the former chair of the San Diego County Air Pollution Control District Hearing Board. Mr. Jones earned a bachelor of arts degree from the University of California, San Diego, and a master of science degree from Colorado State University.

Mr. Baca, 46, of Solvang, is an Engineering Geologist for the County of Santa Barbara, where he has worked since 1989. Previously, he was an Exploration Geologist for the Unocal Corp. Mr. Baca is a member of the American Association of Petroleum Geologists. He earned a bachelor of science degree from California State University, Northridge, and a master of arts degree from the University of California, Santa Barbara.

Mr. Hablitzel, 50, of El Dorado Hills, is the Principal Landscape Architect for The HLA Group/Landscape Architects in Sacramento, where he has worked since 1980. He is a member of the American Society of Landscape Architects and the California Park & Recreation Society. Mr. Hablitzel earned a bachelor of science degree from the California Polytechnic University.

Ms. Rose, 36, of Oakland, is the Staff Scientist at the Environmental Law Foundation. Previously, she was the Conservation Director at the South Yuba River Citizens League. Ms. Rose earned a bachelor of arts degree from California State University, Sacramento, and a master of science degree from the Antioch New England Graduate School.

Mr. Tepel, 63, of San Jose, is a retired Engineering Geologist from the Santa Clara Valley Water District, a position he held since 1977. Previously, he was an Engineering Geologist at W.A. Wahler & Associates from 1969 to 1977. Mr. Tepel is the founder of the California Council of Geoscience Organization. He earned a bachelor of arts degree from the Los Angeles State College.

Ms. Thompson, 47, of Bakersfield, is President of San Joaquin Energy Consultants, Inc., a position she has held since 1997. She is a California registered geologist and hydrogeologist. Ms. Thompson is a member of the American Association of Petroleum Geologists, San Joaquin Geological Society and Technical Advisory Committee of the California Board

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of Registration for Geologists and Geophysicists. She earned a bachelor of science degree from Stanford University.

The Board represents the State's interest in the development, utilization and conservation of mineral resources; reclamation of mined lands; and development of geologic and seismic hazard information. Members do not receive a salary. These positions require Senate confirmation.

Governor's Office

It is estimated that there may be more than 30,000 abandoned and inactive mine locations in the state. If you know of or find an abandoned mine, please call and report it to the Abandoned Mine Lands Unit. The toll free number for reporting an abandoned mine is:

1-877-OLD MINE

Remember to stay out and stay alive!

STATE MINING & GEOLOGY BOARD

ROSTER

Brian Baca	2001-2005	Registered Geologist with background and experience in mining geology.
Robert Griego	1999-2003	Representative of local government with background and experience in urban planning.
Robert Hablitzel	1998-2002	Landscape Architect
Allen M. Jones, Chairman	1999-2003	Mineral resource conservation, development and utilization.
Richard Ramirez, Vice Chairman	1998-2002	Non-specialized public member.
Maureen Rose	2001-2005	Background and experience in the field of environmental protection and the study of ecosystems.
Robert Tepel	2000-2004	Registered Geologist, Geophysicist, Civil Engineer with background and experience in seismology.
Donna Thompson	2000-2004	Background and experience in groundwater hydrology, water quality and rock chemistry.
VACANT	2001-2005	Mining Engineer with background and experience in mining in California.

AML Unit Plugs Dangerous Mine Shaft with Foam

For the past three years, the Abandoned Mine Lands Unit (AMLU) has provided the public with a toll-free number (1-877-OLD-MINE) to report unsafe abandoned mines as part of its "Stay Out - Stay Alive" mine hazard awareness program. Since the establishment of this outreach program, literally dozens of abandoned mines have been reported by the public and inventoried by AMLU staff.

The "prospect" shaft as it originally appeared next to the residence in Weimar.

One such report regarded a dangerous open mine shaft in the town of Weimar in Placer County. The shaft was discovered by three children playing in the woods bordering their home. The shaft was about six feet wide and over thirty feet deep. Since there was no other surface or underground workings associated with the shaft it was assumed to be an exploration excavation by a gold prospector.

This type of excavation was common in prospecting, and is similar to thousands of other exploration shafts found throughout California. Since most of these excavations never resulted in mineral production, they were not considered mines and no record of their locations were ever made. As a result, thousands of these artifacts of mining exploration have never been reported and today pose a hazard to public safety.

How NOT to plug a shaft! The two teenagers driving this vehicle survived their sudden encounter with an unmarked "prospect" shaft.

The abandoned shaft was located on BLM land, jointly administered by the Bureau of Reclamation and the Auburn State Recreation Area. The site had no roads, little exposed waste rock, and, other than the shaft itself, was undisturbed. Since the shaft was located within the Auburn State Recreation Area, a backfill method had to be used which would cause no additional disturbance. This required that all backfill material come from off-site and be hand-carried to the shaft.

A new and innovative polyurethane foam product tested by the Colorado School of Mines and demonstrated by the U.S. Forest Service to be practical for use in mine shaft closures, turned out to be the answer. Polyurethane foam or "PUF" has been used in mining for reinforcing rock strata, creating water barriers, and plugging adits and shafts for more than 20 years. Normally, the PUF is mixed and pumped from tanks on a truck; however, the limited access on-site precluded using this traditional method. The new product comes pre-packaged and can be mixed "in-the-bag" on-site which made it both an ideal product for evaluation, and appropriate for the limited access presented by the shaft.

The Weimar shaft being prepared for the foam plug.

Lowering the foam base for the plug.

The developer of the new foam product, Foam Concepts, Incorporated, offered to provide both a demonstration and free training to AMLU staff in the application of the product for the cost of materials. The day before the closure, staff completed site preparation which consisted of minor clearing around the shaft and placement of safety barriers and an overhead tarp to prevent rain and snow from interfering with the mixing and pouring process. Staff also prepared a six-inch foam “foundation” with ropes

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Look Who's New at OMR!

The new year turned out to be a real windfall for OMR's Reclamation Unit. Two new staff biologists, Vicki Lake and Michael Eichelberger, joined the unit in early January.

Vicki brings with her over 10 years of experience in botany, environmental impact assessment and mitigation planning, and land use regulation. She received a bachelor of science in biological sciences and a master of science in ecology, both from the University of California at Davis. Vicki was previously employed as a botanist and wetland specialist at a Sacramento-based environmental consulting firm, Jones & Stokes, and as a land use planner for the County of Nevada. She has expertise in conducting biological resource inventories, delineating jurisdictional wetlands, restoring native habitats, and controlling invasive weeds. Vicki has conducted environmental project reviews and ensured consistency with CEQA and other pertinent state, federal, and local regulations.

Vicki Lake

Michael comes to us fresh from Viceroy Gold's Castle Mountain Mine in eastern San Bernardino County where he was the reclamation manager for the past three and a half years. In addition to his industry experience, Michael is well qualified for his duties having earned a bachelor of science in plant science from Utah State University, a master of arts in biology from Humboldt State University and a doctorate in toxicology/molecular biology, also from Utah State University.

Michael Eichelberger

Prior to earning his doctorate, Michael worked as a researcher both in academics and for the government conducting research in plant physiology, plant pathology, and soil microbiology.

Vicki and Michael are both looking forward to meeting and talking with all the lead agencies and operators. In fact, they invite you to contact them regarding any biological concerns or questions, or just to share your own experiences relating to biological issues. They can be reached by calling this office at (916) 323-8567.

2001 Lead Agency Contact List Now Available at OMR's Website

The Lead Agency Contact List published last year has been updated for 2001 and is available for viewing at our website which can be found at http://www.consrv.ca.gov.

The list identifies the primary SMARA contact(s) for each lead agency and provides the name, title, department, mailing address, phone number, facisimile number and e-mail address (if available) of each contact. Copies of the list will not be mailed to lead agencies this year; however, users of our site are free to print the list from our web page.

Due to the inevitable changes in staffing, phone numbers and addresses, we anticipate that some of the information in the list may become outdated during the next year. As this occurs, we ask your help as users of the list to keep us informed of any changes by faxing or e-mailing the new information to this office. Our fax number is (916) 322-4862 and our e-mail address is omrcal@consrv.ca.gov.

By providing this list to our readers we hope to improve communications between lead agencies regarding SMARA issues and information. Our goal is to help make administration of the Act more efficient and equitable from one jurisdiction to the next.

Andrew Rush,
Environmental Specialist

AML Unit Plugs Dangerous Mine Shaft with Foam

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imbedded in it to facilitate lowering it into place within the shaft. The foam foundation acted as a base for pouring the final foam plug.

Rick Rajkovich, the developer of the polyurethane foam product demonstrates it's quick set-up and strength as the children who found the shaft look on.

The following day staff completed the process by mixing and pouring approximately six cubic yards of foam into the shaft. The top of the foam plug was kept two feet below the collar of the shaft to allow for a final layer of earth fill. Pouring the plug took less than 90 minutes, including set-up of the material. Several days after the plug was poured, the two feet of earth fill was added to protect the PUF plug from fire and UV radiation. A native seed mix and a straw mulch was applied over the top of the fill to promote revegetation and prevent erosion.

The completed shaft closure in Weimar.

Steve Newton-Reed,
Research Specialist

Executive Officer's Report

At its December 14, 2000 regularly scheduled business meeting held in Sacramento, the State Mining and Geology Board took the following actions on these SMARA issues:

1) Adopted resolutions certifying the revised surface mining ordinances for the Counties of Santa Clara and El Dorado, and the City of San Bernardino, as being in accordance with the requirements of the Surface Mining and Reclamation Act of 1975.

2) Accepted the Annual Surface Mine Inspection Reports for the following mines: Oat Hill Quarry (American Canyon City); Otay Ranch Pit (Chula Vista); Painted Hills Mine (Desert Hot Springs); Garnet Pit (Palm Springs); Martis Valley Site (Truckee); and, Sha-Neva Plant #2 (Truckee). The board is the lead agency for these surface mines until the local jurisdictions adopt surface mining ordinances.

3) The board conducted the following appeals hearings: Hearing: California Mine ID #91-42-0004, Parks Land and Cattle Company, Santa Barbara County. Public Resources Code § 2207 requires each mine operator to submit an annual reporting fee. The amount of this fee is determined under California Code of Regulations (CCR) § 3695 et seq., and generally is based upon the previous calendar year's production. A special exemption from the annual fee amount is provided for under CCR § 3699 – Low Gross Exemption. The operator appealed the denial by the Department of Conservation of its claim to a low gross exemption on the basis that if one averaged the operation's income over the previous four years, the average annual income would qualify the operation for the low gross exemption (which is less than $100,000 per year). The board denied the operator's appeal, because the regulations do not allow for the averaging of several years' incomes, but require the low gross exemption to be applied to a single year's gross income.

Hearing: California Mine ID #91-09-0002, Weber Creek Quarry, in El Dorado County. The operator appealed the denial by El Dorado County of its financial assurances in the amount of $170,000. According to the county's findings, a revised financial assurance amount of $206,080 was necessary to meet the requirements in the approved reclamation plan. The board denied the operator's appeal and upheld the county's decision to increase the financial assurance amount to $206,080. The board noted ten major deficiencies in the operator's considerations in determining its proposed $170,000 amount. The

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Executive Officer's Report

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board also noted that it believed the county approved amount was significantly less than sufficient to reclaim the site, and urged the county to reconsider the amount in light of the deficiencies cited by the board.

At its January 11, 2001 regularly scheduled business meeting held in Sacramento, the board took the following actions on these SMARA issues:

1) The board accepted DMG Open File Report 2000-03, *Mineral Land Classification of El Dorado County, California,* and DMG Open File Report 2000-18, *Mineral Land Classification of Concrete Aggregate Resources in Tehama County, California,* as being prepared in accordance with the board's guidelines. These new mineral classification reports have been distributed to their respective counties for incorporation into the counties' general plans.

At its February 8, 2001 regularly scheduled business meeting held in Sacramento, the board took the following actions on these SMARA issues:

1) The board received a report from the Department of Conservation on the results of an inspection of the Garden Valley Aggregates mine site. This site, which had been allowed to operate for over 20 years in El Dorado County without benefit of a reclamation plan or financial assurance, was declared "reclaimed" by the county in 1999. The county maintains that the reclamation was accomplished in accordance with conditions of a 1971 use permit; however, local residents challenged this on the basis that the permit was not for aggregate mining and was issued to a former owner of the land. The department's report concluded that the site was not reclaimed according to SMARA standards.

At its March 8, 2001 regularly scheduled business meeting held in Sacramento, the board took the following actions on these SMARA issues:

1) The board received and accepted the annual inspection reports for Weber Creek Quarry and Diamond Quarry, both located in El Dorado County. Since March 2000 the board has taken responsibility for conducting annual mine inspections for the county. Initially, the board's inspector attempted to complete inspections of both of these quarries in November 2000; however, the same operator for both sites forbade the inspector from making a complete inspection. The board was forced to obtain court warrants to complete the inspections, which it did in late January 2001. The reports received by the board demonstrated both quarries to be seriously out of compliance with their respective approved reclamation plans. The board indicated that the degree of non-compliance with the current reclamation plans was so severe that it recommended the county require new reclamation plans for both sites. Also, the board noted that one site has no financial assurance mechanism in place, and that the financial assurance amounts for both quarries are substantially less than adequate to cover reclamation costs. The board determined to review the county's actions to enforce corrective measures for these two quarries at its April 12, 2001 meeting, and indicated that it may issue a 45-Day Notice to Correct Deficiencies to the county at that meeting if it is not satisfied with the county's enforcement activities.

2) The board reviewed and accepted the Annual Mine Fee Schedule for Reporting Year 2000. There are no increases in annual fees for the 2000 Reporting Year.

3) The board issued an administrative order against California Mine ID # 91-33-0003, Painted Hills Mine, in the City of Desert Hot Springs, for its failure to provide evidence of an adequate financial assurance. The board is the acting lead agency for this mine until the city produces a surface mining ordinance. The administrative order, which carries with it a monetary penalty, automatically will be reviewed at the board's April 12th meeting when an effective date for the order will be determined.

John Parrish, Ph.D.
Executive Officer

Reclamation Tips

Where's the Nitrogen?

Once, a particularly bright engineer proposed building and launching a spacecraft to a distant planet in another solar system. In this spacecraft he intended to include the plans for a robot, a robot that was to prepare an inhospitable planet with all of the conditions necessary to sustain human life. Design of the rocket that would lift the spacecraft into orbit and then direct it to its destination would require a great deal of miniaturization in order to reduce weight and therefore conserve fuel. Since there would be limited room on the spacecraft, the robot itself would not be constructed until it reached the planet, where it would have to read the specifications of its own blueprints and then construct itself using resources available at its destination. No small engineering feat and certainly a very ambitious plan.

During its self-construction and functioning thereafter, the robot would require an energy source to power its systems and build the individual components that would sustain it as a fully functioning unit. The only energy source at its disposal would be sunlight that it would convert to useful energy by photoelectric systems. All of the building materials for construction and expansion are derived from the air, water and the soil. The robot's construction would be elaborate and consist of trillions of microscopic sub-units each with their own power stations, manufacturing plants, communication systems, waste management systems, security systems, and planning departments. The robot would even be programmed to replicate itself and make almost exact copies that would function just like the original. There were many other features that distinguished the robot but are to numerous to describe here.

The engineer worked at a company that, as a public service, offered tours to high school science classes. One day after escorting a group of students through the facility, a student asked what his job was and what he was working on. The engineer eagerly described his project and went into great lengths discussing the robot. When he was done he asked if there were any questions. From the back of the crowd of students came a voice that said, "Excuse me mister, why don't you just send a plant seed."

When you look at a mine overburden pile or a pit floor or maybe a gravel quarry, what do you notice first? Well its obvious isn't it? Where are the plants? Of course, there are no plants because this is a mine and mines remove vegetation, overlying soils, and overburden rock to access the mineral of interest to be mined. What is left behind after mining is not exactly an Iowa corn field. Mostly, what it looks like is an inhospitable planet in a far off solar system! Although the analogy of the robot and the plant is accurate, to carry out its basic functions a plant needs some basic resources to fulfill the tasks outlined in the analogy.

Among the basic plant needs, inorganic essential elements from the soil are vital and of these none are needed in higher amounts than nitrogen. Nitrogen is required as a component of amino acids, proteins, nucleic acids, chlorophyll and many other components of the plant. There are several forms of nitrogen in the soil but the plant root can absorb only nitrate (NO^{3-}) or ammonium ion (NH_4^+) and only ammonium ion is used in metabolism. All other forms of nitrogen are unavailable to the plant, which depends on bacterial nitrogen fixation and bacterial degradation of humus for its source of nitrogen. The conversion of nitrogen gas from the atmosphere to ammonia is known as nitrogen fixation. Although the other mineral nutrients such as phosphorus, sulfur and potassium are derived from the soil, the ultimate source of nitrogen is from the air where it makes up 79% of the atmosphere.

Anyone who gardens or has houseplants has bought fertilizers and may have noticed the three numbers on the packaging (i.e. **20 10 10**). These numbers are not meant to be a secret code although many people don't understand what they represent. The three numbers express the concentrations in percentage by weight of the "big three" essential elements (listed in the order nitrogen, phosphorus, and potassium) required by plants for their growth and development. Large amounts of these elements are applied in agriculture in order to sustain high yields and profitability, but there are good reasons to limit the application of fertilizers in reclamation. Most native species are adapted to low

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Reclamation Tips

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nutrient levels and the application of fertilizers encourages the spread of weeds and can be deleterious to the development of healthy soil microbial systems. An alternative to adding large amounts of nitrogen is by adding a permanent source of nitrogen and by altering the nutrient availability of the soil.

Plants cannot fix nitrogen, only bacterial cells can do this. There are several types of bacteria that fix nitrogen including free living forms and those associated with other organisms in a symbiotic relationship. There are two significant types of nitrogen fixing associations with higher plants, the legumes associated with *Rhizobium* bacteria and a group of trees and shrubs from eight different plant families that form associations with the bacteria *Frankia*.

The use of legumes as a rotational crop in agriculture has been used for years and an entire industry has developed around the isolation of specific strains of *Rhizobium* as inoculant for the legumes. Native legumes are also excellent sources of nitrogen fixation and many would be useful in reclamation as a way to enrich the soil. Plant species from genera such as milkvetch (*Astragalus*), lupine (*Lupinus*), mesquite (*Prosopis*) and native clovers *(Trifolium)* might be considered.

A second group of plants that are mostly trees and shrubs from over 25 different genera form associations with filamentous bacteria called actinomycetes. Many actinomycetes are beneficial soil organisms that are responsible for decomposing organic material in the soil. These organisms give compost its characteristic "earthy smell". There are several different genera of actinomycetes but one called *Frankia*, associates with certain trees and shrubs and together they form nitrogen-fixing nodules on the roots of the host plant. These associations are called actinorhiza. Native California plants that are actinorhizal include species of alder (*Alnus*), wild lilac (*Ceanothus*), and bitter brush (*Purshia)*.

A third group of useful plants to consider for establishing a good nitrogen balance in the soil would be perennial grasses and composites. Although neither of these groups of plants are involved in nitrogen fixation both readily form associations with mycorrhizae that foster soil structure and development that is favorable for soil microorganisms involved in nitrogen cycling.

California is an ecologically diverse state with mine reclamation activity occurring in diverse habitats ranging from hot dry deserts to cool wet coniferous forests. Although the habitats are diverse, in almost all cases, nitrogen fixing species of plants are available for reclamation.

Michael Eichelberger, Ph.D.
Environmental Specialist

Native Plants That Form Symbiotic Nitrogen Fixing Associations

Legumes

Acacia	Catclaw
Astragalus	Milkvetch
Lathyrus	Wild Pea
Lotus	Birds-foot Trefoil
Lupinus	Lupine
Oxytropis	Locoweed
Prosopis	Mesquite
Trifolium	Clover
Vicia	Vetch

Actinorhizal Plants

Alnus	Alder
Ceanothus	California Lilac
Cercocarpus	Mountain Mahogany
Myrica	Wax Myrtle
Purshia	Antelope Bush
Sheperdia	Buffalo Berry

What's Going On

Editor's Note: This column lists educational conferences and workshops related to mining and mine reclamation that will be occurring in the near future.

10th Annual Integrated Mining and Land Reclamation Planning Workshop
April 23-27, 2001
The Flamingo Hilton
Reno, Nevada
Cost: $450.00
Information: Dr. Yung Sam Kim
(925) 757-7547

Mycorrhizae in Reclamation

What are Mycorrhizae?

First described more than 150 years ago, mycorrhizae (pronounced my ko ri zee) are symbiotic relationships between fungi and plant roots. Mycorrhizae are referred to as mycorrhizal associations because they are not a fungus or a plant but rather a specific structural association between a soil fungus and a plant root. These associations are highly evolved and benefit both partners, with the plant receiving essential nutrients (especially phosphorus), water, and protection from disease causing organisms while the fungus receives sugar from the plant that it in turn uses as food to grow, develop, and reproduce. Their importance in the soil community can not be understated if for no other reason than simply their relative abundance. It has been estimated that there may be as much as 7,000 pounds of microscopic mycorrhizal hyphae per acre in certain rich soils. Hyphae are the microscopic strands that is the body of a fungus.

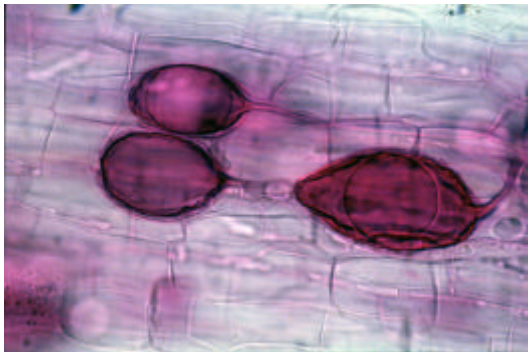
Although mycorrhizal associations are most often described in accordance with how they benefit plants, perhaps a better perspective would be regarding how they influence the total soil environment. Mycorrhizal fungi are unique in the soil ecosystem because unlike other soil microorganisms they do not derive their energy from soil organic matter but they do withdraw nutrients from the soil which they in turn pass on to their associated plants. Mycorrhizae have great influence on both the physical parameters of soil and the microorganisms in the local soil environment.

The mycorrhizal hyphae form a connecting "net" within the soil and the associated plant roots. It has been shown that the hyphal strands excrete a protein material called glomalin. This material coats the soil particles and adheres them together into aggregates, thus giving the soil structure. Soil structure is critical in a healthy soil environment providing pores and channels that are essential for the percolation of water, aeration and spaces for soil organisms to live.

Two Important Types of Mycorrhizae

There are at least 7-different types of mycorrhizal associations but for the reclamation practitioner, only two are of significant importance, these being ectomycorrhizae and endomycorrhizae. It is extremely important to understand the difference between these two mycorrhizal types since the kinds of plants that fungi of each group associate with are generally quite different.

Ectomycorrhizal fungi include many of the mushrooms, puffballs, coral fungi and truffles that are familiar during the wet months of the year in California. Although the fruiting body is obvious to the casual observer, the bulk of the fungus occurs as microscopic hyphal strands out of site in the soil and allied with the roots of plants. Following inoculation of trees with ectomycorrhizal fungi, the appearance of fruiting bodies (mushrooms) after the rains may be a positive indication that mycorrhizal associations have formed. Ectomycorrhizal fungi are associated with California's native oaks, willows, alders, cottonwoods and most of the conifers, specifically the pines, hemlocks, firs (including Douglas fir) and spruce. Ectomycorrhizal inoculation would therefore be useful in reclaiming areas utilizing these forest and riparian species as revegetation components, but not in reclaiming areas to be planted with grass or most shrubs (there are exceptions, in particular the shrubby oaks).



Vesicles in the root cells of host plant.

Two structural features characterize ectomycorrhizal associations. The term "ecto" denotes "outside." Although the fungal hyphae penetrate into and between the cells of the root, they do not penetrate into the interior of the root cells. Inside the root cortex the hyphae ramify around the cells. The intimate association of hyphae with the root cells is called the "hartig net" and is the site for the transfer of nutrients and sugars between the fungus and the plant root cells. The other important feature of this type of

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Mycorrhizae in Reclamation

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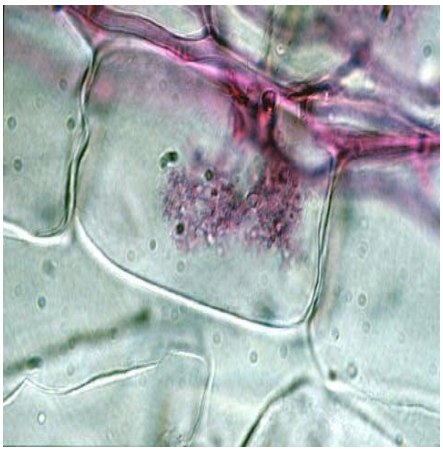
mycorrhizal association is the formation of a "mantle" on the short lateral roots of the host plant. The mantle consists of interwoven hyphae that forms a sheath around the root and among other things is thought to create a barrier against soil-borne plant pathogens.

Endomycorrhizae, also known as vesicular-arbuscular mycorrhizas (VAM) have fungal partners that are primitive and produce only microscopic structures. These fungi do not produce large complex fruiting bodies like the mushrooms of the ectomycorrhizal fungi and their presence can only be detected by analyzing the roots of the associated plants for their occurrence or by sieving the soil for their spores. Although there are thousands of ectomycorrhizal fungi, many of which are restricted to a narrow host range, there are only about 150 known species of endomycorrhizal fungi and collectively they are capable of forming mycorrhizal associations with perhaps 90% of the worlds higher plants.

Unlike ectomycorrhizal fungi, endomycorrhizal fungi do not form a mantle on the exterior of the root but they do penetrate into the interior (hence the prefix "endo") of plant root cells where the hyphae form complex branching structures called arbuscules. Arbuscules are the site of nutrient-sugar exchange between the fungus and the plant root cell. Endomycorrhizal fungi may also produce thickened swellings of the hyphae that are known as vesicles. Vesicles function to store lipids for food storage and they may also become thick walled and serve as propagules. The acronym "VAM" is taken from the first letter each of vesicle, arbuscule, and mycorrhizae.



Arbuscle, in a host plant

Mycorrhizal fungi favor associations with plants that have coarse root systems. The fungus grows out from the root in thread like strands called hyphae that ramify out through the soil and absorb nutrients that are effectively unavailable to the plant root. It is believed that this confers a competitive advantage to the plant and greatly enhances its probability of survival, growth, and development.

Reintroducing Mycorrhizal Fungi

Mine reclamation sites are typically highly compacted and stripped of topsoil, two factors that severely limit the establishment of a soil microbial community and the associated plant cover. Species lists for revegetation usually contain plant colonizers, local native species that invade disturbed sites. These particular plants can be very useful in establishing a quick plant cover that effectively reduces erosion and invasion by weeds, reintroduces much needed organic material into the rooting zone and serve as nurse plants for other species.

Although plant colonizers are important tools in reestablishing plant cover, establishing a sustainable plant community characteristic of pre-mining activity will require the introduction of native perennials, species that require soil structure and microbial activity to facilitate their growth and development. Plant colonizers are adapted to harsh sites and many do not form mycorrhizal associations, a key function in reintroducing the microbial soil component.

Reintroduction of mycorrhizal fungi to reclamation sites is facilitated by many different techniques, but the proper salvage, care and reintroduction to the site with native topsoil, is by far the best method. Most of the beneficial soil organisms including mycorrhizal fungi can be reintroduced into the reclamation site if the topsoil has been properly stockpiled. Mycorrhizal fungi remain as propagules consisting of spores, hyphae attached to living roots and living roots colonized by mycorrhizal fungi.

Salvaged topsoil should be stored for as little time as possible, planted with perennial grasses and members of the sunflower family, plants that are aggressive mycorrhizal formers, to maintain VAM propagules. The topsoil should be stacked no higher than the rooting zone of the

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Mycorrhizae in Reclamation

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host mycorrhizal plants, and left undisturbed until use. Remember that mycorrhizal fungi require a host plant root to supply it with its nutritional needs; these fungi cannot derive energy from decaying matter like saprophytes and therefore can not survive long in the absence of the host plant. Simply leaving the stockpiled soil bare and allowing weeds to establish as a cover does little good since most weeds do not form mycorrhizal associations and therefore do not foster a microbial environment in the soil. Bare stockpiled topsoil or one with a weed cover will soon become deficient in beneficial microbial organisms and mycorrhizal fungi in particular.

An alternate method for site inoculation is the transplanting of native mycorrhizal plants from surrounding native soils. Since virtually all of the native species in undisturbed areas will be mycorrhizal this method provides a local source for inoculation within the revegetation project. Several problems exist with this technique. First, this practice requires the disturbance of additional acreage incidental to mining activity. It would be far better to remove and transplant specimens from areas destined for future disturbance to current reclamation sites. Unfortunately, many species do not lend themselves well to transplanting and those that do should be transplanted while dormant in the late fall or winter if weather permits. Transplanting with inoculated plants does not insure immediate inoculation for the entire revegetation site. Mycorrhizal fungi spread slowly, in particular the VAM fungi spread at best about a meter per year from their point of origin and to form a net the plants need to be planted in close proximity to facilitate contact between the roots by the fungi in the soil.

If topsoil has been improperly stockpiled resulting in loss of inoculation potential or if topsoil is limiting, the introduction of mycorrhizal fungi to the site may require the use of cultured inoculum. Mycorrhizal strains native to the site would be ideal but is almost always impractical to obtain. The alternative is the purchase of commercial inoculum from one of the many firms now marketing both ectomycorrhizal and endomycorrhizal products.

Commercial inoculum can be purchased in many forms including those that are applied dry and those that are applied in a liquid. Dry Formulations may be mixed in vermiculite, sand or clay granules. Successful methods of application have included imprinting, broadcast/ harrowing and two-stage hydroseeding. Seedlings can be dipped in a liquid mycorrhizal inoculant to coat the roots. Whatever form is purchased or regardless the method that the inoculum is applied, it must be delivered to the rooting zone where the inoculum will be in close contact with the host roots. Remember that the fungal partner depends solely on the host plant partner for its nutritional needs and can not survive long on its own. This also means that the timing of inoculation should coincide with growth and or germination. Improper application or poor timing during the year can be a waste of mycorrhizal inoculant, time, and money.

Cultural practices may control or limit effective mycorrhizal inoculation. It is well known for example that high phosphorus levels inhibit colonization of plant roots. Plants do not appear to be passive unwilling partners in the mycorrhizal formation and in fact they produce molecules that are released in root exudates that regulate mycorrhizal formation. Plants regulate mycorrhizal formation through responses to internal plant phosphate levels and the application of fertilizers may have a strong negative influence on root colonization and may cause more harm in the long run than good in the short term. Overuse of pesticides and fertilizers such as used in highly managed agriculture systems are deleterious to establishing mycorrhizal associations and a stable microbial community. Mine reclamation sites should not be managed as if they were agricultural sites. Different ideas and approaches must be implemented and the use of natural processes must be followed in order to achieve a resemblance of a pre-mined site.

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Environmental Specialist

On a Final Note...

For the past three years I have had the honor of being the editor of this newsletter. But now it's time for me to move on to new horizons. I have taken a position with another division in the department to work with Resource Conservation Districts.

I want to thank those readers who provided me with their ideas and support during my time as editor. I would also like to extend many thanks to my coworkers for the fine articles they provided me to fill these pages with. They not only made my task as editor easy, but they taught me a lot about mine reclamation and, to be honest, life in general. It is my hope that our combined efforts have done the same for you our reader.

Andrew Rush

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